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EFFECTS OF CANOPY GEOMETRY ON THE SPINNING CHARACTERISTICS OF A CROSS PARACHUTE WITH A W/L RATIO OF 0.264

By
William P. Ludtke

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NAVAL ORDNANCE LABORATORY, WHITE OAK, SILVER SPRING, MARYLAND

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The effects of cloth permeability, number of suspension lines, suspension line length, and hem configuration on the spinning characteristics and aerodynamic drag force of the cross parachute were investigated in a wind tunnel. Forty-inch-diameter models with a canopy arm width-to-length ratio (W/L) of 0.264 were tested at various velocities from 50 feet per second to 300 feet per second. Tests were conducted with a conventional cross parachute and with modifications to the skirt hem which represented an interpanel cord and a band of cloth. The width of the cloth band was ten percent of the canopy diameter. Results of these tests demonstrate that the parachute geometry does have an effect on the drag capability of a spinning cross parachute. While some trends were evident, the effects of geometry on the parachute spin rate for the different hem configurations varied.

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NAVAL ORDNANCE LABORATORY
SILVER SPRING, MARYLAND

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Effects of Canopy Geometry on the Spinning Characteristics of a Cross Parachute with a W/L Ratio of 0.264

The investigation presented in this report is related to the improvement of parachute technology.

ROBERT WILLIAMSON II
Captain, USN
Commander

a. E. Seigel
A. E. SEIGEL
By direction

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LIST OF SYMBOLS

D	drag force, pounds
C_D	coefficient of drag
V	velocity, feet per second
ρ	density of air, slugs/ft^3
q	dynamic pressure, lbs/ft^2
So	canopy reference area, ft^2
L	length of canopy arm
W	width of canopy arm
W/L	canopy arm width-to-length ratio
C	denotes clockwise rotation of the canopy when viewed from behind the parachute
CC	denotes counterclockwise rotation of the canopy when viewed from behind the parachute
RPM	revolutions per minute

DEFINITIONS

permeability - rate of airflow through cloth in ft^3/ft^2/min when measured under a pressure differential of 1/2 inch of water

percent reefed - ratio of the drag force produced in the reefed condition to the drag force of the fully inflated parachute at the same velocity

INTRODUCTION

Wind-tunnel tests and field tests of various cross parachute configurations have demonstrated reliable inflation and good aerodynamic efficiency at subsonic, transonic, and supersonic velocities. A serious problem, sometimes encountered, arises from the tendency of the inflated cross parachute to rotate about the parachute axis at such a rate as to twist the suspension lines into a single riser, thus causing collapse of the parachute canopy. In some applications, this undesirable feature can be overcome by use of a swivel mechanism. However, in many high-performance applications, the required swivel can be very large and/or costly.

Observation of the cross parachute in field tests indicated that the spinning is affected by:

a. Cloth permeability

b. Suspension line length

c. Independent motion of the four arms of the canopy

A series of wind-tunnel tests were proposed to:

a. Determine the effects of cloth permeability, suspension line length, number of suspension lines, and velocity on the spinning characteristics of the cross parachute

b. Determine the effect of modifying the canopy hem configuration by an addition of (1) hem wire and (2) hem band on the spinning characteristics of the cross parachute

c. Determine the drag coefficient of the various spinning configurations under test

APPROACH

Three series of model cross parachutes were designed, using a canopy cloth of different air permeabilities for each series. All models consisted of two panels 40 inches in length with a W/L = 0.264. The two panels were arranged to form the configurations illustrated in Figure 1. Each series of models consisted of three parachutes with 8, 16, and 24 suspension lines, respectively, for the same canopy cloth. As initially installed, the suspension lines were 1.8 canopy diameters in length. These lines were later shortened to 1.6 and 1.4 canopy diameters. This approach provided 27 possible geometric configurations for each hem modification. Parachute construction details

are illustrated in Figure 2, and the materials used in construction of the models are enumerated in Table I.

The wind-tunnel tests were conducted at the University of Maryland 7-foot by 11-foot Cross Section Subsonic Wind Tunnel, College Park, Maryland. The wind-tunnel support system, Figures 3, 3A, and 3B, was designed to position the model canopies. To maintain a relatively aerodynamically uncluttered test section, guy wires were used to support the instrumented test body. In all tests, the parachute suspension lines were attached to a spider at the rear of the test body. The shaft of the spider was mounted to a swivel which was in turn connected to a tension-type force transducer ring for sensing aerodynamic drag force. The addition of a light source and photographic cell pickup counted the revolutions of the shaft. The instrumentation setup is shown schematically in Figure 4, and the readout equipment is pictured in Figure 4A.

Each parachute was mounted onto the spider, and measurements of the spin rate and aerodynamic drag force were made at various wind-tunnel velocities from 50 feet per second through 300 feet per second. Upon completion of one hem configuration, the hem was modified, and the tests were repeated. The first series of tests was conducted without any constraints on the canopy hem. The hem was then modified by the addition of a 1/16-inch flexible steel cable which was added between rings attached to the hem of the canopy at the outer suspension lines. This hem wire was to preclude independent motion of the canopy arms. In order to assure a tensile load in the hem wire, the canopy was partially reefed. A typical hem wire installation is shown in Figure 5. The second hem modification consisted of a four-inch wide band of cloth, the same cloth as the canopy, attached around the skirt hem of each configuration. A typical hem band installation is shown in Figure 6.

Test data were reduced to coefficient form by means of the following formulae:

$$C_D = \frac{D}{qSo}$$

$$q = \frac{1}{2} \rho V^2$$

$$So = 2LW - W^2$$

$$\text{percent reefed} = \frac{\text{drag of parachute in reefed condition at velocity V}}{\text{drag of fully opened parachute at same velocity}}$$

The reference area of all parachute models used in this test is 5.092 ft^2.

RESULTS

From observation of previous field tests and wind-tunnel tests of the cross parachute, it was anticipated that the results of this investigation would indicate the following:

a. Parachute spin rate would increase as cloth permeability decreases

b. Parachute spin rate would increase as suspension line length increased

c. Modification of the hem would produce a reduction in spin rate

d. Effect of the number of suspension lines was unknown

The wind-tunnel test series was run with the 208 $ft^3/ft^2/min$ permeability canopies tested first, since their inherent stability put the least amount of undue strain on the swivel and strain gage link in the test body. The 80 $ft^3/ft^2/min$ canopies, which were tested next, showed some tendency to cone. Finally, the relatively impervious 8 $ft^3/ft^2/min$ canopies were mounted on the test body. These parachutes were very unstable in that they exhibited a coning motion about the wind-tunnel center line at an angle of 30 degrees $\pm$ 10 degrees and oscillated back and forth. The swivel mechanism failed under this strain. It was not deemed feasible to continue testing the low permeability parachutes.

All of the parachute configurations, except one (eight suspension line, 80 permeability, canopy), rotated in a clockwise direction when viewed from a position downstream of the parachute. The aforementioned parachute rotated in a counterclockwise direction for all hem modifications. As a comparison, a 24-gore, 16 percent geometrically porous, 37-1/2-inch flat diameter, 5-ribbon ring slot parachute and a 24-gore, 24 percent geometrically porous, 37-1/2-inch flat diameter, 9-ribbon ribbon parachute were tested through the velocity range of 50 to 300 feet per second. As the velocity was increased on the ring slot parachute, the rotation rate increased until the spinning canopy was distinguishable only as a blur. This was a much faster spin rate than any of the cross parachutes had achieved. Upon reaching 300 feet per second constant velocity, the ring slot parachute ceased rotation then reversed direction and spun at a low constant rate. The ribbon parachute, when subjected to the same test, exhibited a slow constant roll in the same direction for all test conditions.

The cross parachutes, when turned inside out, would reverse their direction of rotation; however, the ring slot and ribbon canopies continued to rotate in the same direction.

The effects of velocity on the parachute spin rate for the various test parameters (number of suspension lines, suspension line length, hem configuration) are illustrated in Figures 7 through 12. It is difficult to draw general conclusions from these data. Some of the configurations confirm the pretest expectations, but other configurations are contrary to expectation. It is interesting to note that the use of a hem cord, in place of a hem wire, in several field test configurations has reduced the rotation of the cross parachute and maintained full canopy inflation. This is believed to be due to the control of the independent action of the four canopy arms.

In view of the variation in performance for the configurations, further testing is necessary before firm conclusions can be drawn as to the rotational properties of the cross parachute.

Tables II through XX enumerate the drag coefficients of the various configurations, together with the respective spin rates, etc. Some general observations can be made concerning the drag coefficients of the spinning parachutes as affected by the various test parameters.

a. An increase in the canopy cloth permeability is accompanied by a reduction in the drag coefficient.

b. For any given suspension line length, the drag coefficient increases as the number of suspension lines increases. This effect is evident for all hem configurations and cloth permeabilities.

c. For all hem configurations and cloth permeabilities, the drag coefficient increases as the suspension line length is extended.

Comparison of the drag coefficients of the hem wire configurations was made on configurations having the same hem wire length. Comparison of the hem band configurations, due to the several hem band lengths, was made on the basis of configurations having the same percent reefing.

TABLE I

MATERIALS USED IN MODEL PARACHUTE CONSTRUCTION

ITEM	MATERIAL	PARACHUTE SERIES		
		NUMBER 1	NUMBER 2	NUMBER 3
1	CLOTH	MIL-C-7020, TYPE I HEAT SET, AIR PERMEABILITY $8FT^3/FT^2/MIN$ @ 1/2 INCH WATER PRESSURE DIFFERENTIAL	MIL-C-7020, TYPE I	4.75 $OZ./YD^2$, DOBBY WEAVE, AIR PERMEABILITY 208 $FT^3/FT^2/MIN$ @ 1/2 INCH WATER PRESSURE DIFFERENTIAL
2	TAPE	MIL-T-5038, TAPE III, 1/2 INCH WIDE	MIL-T-5038, TYPE III, 1/2 INCH WIDE	MIL-T-5038, TYPE III, 1/2 INCH WIDE
3	SUSPENSION[1] LINE	MIL-C-17183	MIL-C-17183	MIL-C-17183
4	STITCHES[2]	TYPE 301, FED STD 751, 9 TO 12 STITCHES PER INCH, 2 ROWS ON 1/4 INCH NEEDLE GAUGE.		
5	STITCHES	TYPE 301, FED STD 751, 9 TO 12 STITCHES PER INCH, SINGLE ROW		

1 8 SUSPENSION LINE CANOPIES USE, TYPE VI, 500-LB TENSILE STRENGTH
16 SUSPENSION LINE CANOPIES USE, TYPE IV, 300-LB TENSILE STRENGTH
24 SUSPENSION LINE CANOPIES USE, TYPE III, 200-LB TENSILE STRENGTH

2 ALL THREAD, V-T-295. TYPE I OR II, CLASS 1 OR 2, SIZE B

TABLE II PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
61	1.0D	None	50	.688	100	18	CC	Some coning.
			100	.640	100	24		
			150	.618	100	42		
			200	.607	100	60		
			250	.586	100	60		
			300	.584	100	66		
60	1.4D	None	50	.733	100	24	CC	Some coning.
			100	.684	100	42		
			150	.675	100	56		
			200	.662	100	72		
			250	.637	100	60		
			300	.632	100	42		
59	1.8D	None	50	.760	100	24	CC	Some coning.
			100	.709	100	48		
			150	.702	100	60		
			200	.695	100	60		
			250	.681	100	42		
			300	.677	100	42		

TABLE III PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
69	1.0D	None	50	.624	100	48	C	No coning. Force link very steady.
			100	.632	100	96		
			150	.644	100	156		
			200	.648	100	222		
			250	.648	100	300		
			300	.656	100	390		
68	1.4D	None	50	.766	100	48	C	Some coning.
			100	.700	100	102		
			150	.724	100	168		
			200	.728	100	252		
			250	.718	100	348		
			300	.732	100	468		
67	1.8D	None	50	.854	100	36	C	Some coning.
			100	.755	100	84		
			150	.766	100	150		
			200	.777	100	234		
			250	.772	100	342		
			300	.792	100	462		

TABLE IV PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
49	1.0D	None	50	.633	100	6	C	
			100	.663	100	36		
			150	667	100	30		
			200	.674	100	36		
			250	.670	100	72		
			300	.676	100	108		
48	1.4D	None	50	.712	100	12	C	
			100	.712	100	0		
			150	.715	100	6		
			200	.753	100	42		
			250	.753	100	84		
			300	.749	100	138		
47	1.8D	None	50	.691	100	6	C	Some coning.
			100	.716	100	0		
			150	.776	100	12		
			200	.818	100	42		
			250	.800	100	90		
			300	.806	100	144		

TABLE V PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
79	1.0D	7 1/4" Wire	50	.630	91.6	18	CC	
			100	.566	88.4	42		
			150	.568	91.9	78		
			200	.564	92.9	114		
			250	.557	95.1	120		
			300	.550	94.2	120		
75	1.4D	8 1/2" Wire	50	.712	97.1	12	CC	
			100	.633	92.5	36		
			150	.643	95.3	48		
			200	.641	96.8	42		
			250	.618	97.0	54		
			300	.612	96.8	48		
76	1.8D	8 1/2" Wire	50	.745	98.0	12	CC	
			100	.675	95.2	18		
			150	.662	94.3	30		
			200	.652	92.9	42		
			250	.645	94.7	48		
			300	.635	93.8	48		

TABLE VI PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION – HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
77	1.0D	7"Wire	50	.684	109.6	48	C	
			100	.596	94.0	84		
			150	.6.3	95.2	132		
			200	.611	94.3	168		
			250	.609	94.0	222		
			300	.613	93.4	276		
72	1.4D	8 1/4" Wire	50	.730	95.3	60	C	
			100	.685	97.9	108		
			150	.697	96.3	144		
			200	.686	94.2	210		
			250	.690	96.1	288		
			300	.688	94.0	432		
73	1.8D	8 1/4" Wire	50	.745	87.2	54	C	
			100	.728	96.4	102		
			150	.717	93.6	156		
			200	.717	92.3	224		
			250	.706	91.5	258		
			300	.709	89.5	318		

TABLE VII PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION - HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
63	1.0D	6"Wire	50	.642	101.4	6	C	
			100	.600	90.5	0		
			150	.605	90.7	0		
			200	.609	90.4	0		
			250	.607	90.6	18		
			300	.620	91.7	30		
55	1.4D	7 3/4" Wire	50	.727	102.1	18	C	
			100	.697	97.9	30		
			150	.702	98.2	42		
			200	.714	94.8	48		
			250	.700	93.0	78		
			300	.705	94.1	102		
56	1.8D	7 3/4" Wire	50	.718	103.9	6	C	
			100	.719	100.4	24		
			150	.729	93.9	36		
			200	.729	89.1	48		
			250	.719	89.9	54		
			300	.726	90.1	84		

TABLE VIII PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
100	1.0D	7 3/4" Band	50	.681	99.0	12	CC	
			100	.586	91.6	24		
			150	.601	97.2	48		
			200	.592	97.5	66		
			250	.585	99.8	84		
			300	.587	100.5	90		
94	1.4D	8 1/2" Band	50	.754	102.9	12	C and CC	
			100	.681	99.6	12		
			150	.643	95.3	0		
			200	.644	97.3	0		
			250	.635	99.7	0		
			300	.640	101.3	18		
93	1.8D	8 1/2" Band	50	.745	98.0	18	C	
			100	.703	99.2	6		
			150	.681	97.0	6		
			200	.661	95.1	0		
			250	.653	95.9	0		
			300	.658	97.1	0		

TABLE IX PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
101	1.0D	7 3/4" Band	50	.630	101.0	6	C	Coning
			100	.635	100.5	24		
			150	.644	100.0	24		
			200	.631	97.4	48		
			250	.619	95.5	24		
			300	.618	94.2	24		
87	1.4D	8 1/2" Band	50	.585	76.3	30	C	
			100	.691	98.7	54		
			150	.706	97.5	66		
			200	.686	94.2	78		
			250	.668	93.0	78		
			300	.667	91.1	84		
86	1.8D	8 1/2" Band	50	.706	82.7	24	C	
			100	.741	98.1	48		
			150	.732	95.6	60		
			200	.711	91.5	72		
			250	.694	89.9	78		
			300	.678	85.6	78		

TABLE X PARACHUTE TEST DATA

CLOTH PERMEABILITY 80 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
102	1.0D	7 3/4" Band	50	.712	112.5	0	C	Coning
			100	.659	99.4	0		
			150	.643	95.4	0		
			200	.651	96.6	0		
			250	.629	93.9	0		
			300	.624	92.3	6		
89	1.4D	8 1/2" Band	50	.669	94.0	0	C	
			100	.683	96.6	12		
			150	.711	99.4	36		
			200	.699	92.8	54		
			250	.692	91.9	54		
			300	.682	91.1	48		Serving slipped slightly.
88	1.8D	8 1/2" Band	50	.712	103.0	6	C	
			100	.714	99.7	12		
			150	.756	97.4	24		
			200	.734	89.7	30		
			250	.688	86.0	42		
			300	.735	91.2	48		

TABLE XI PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
66	1.0D	None	50	.648	100	0	C	
			100	.613	100	24		
			150	.598	100	36		
			200	.587	100	54		
			250	.584	100	66		
			300	.579	100	78		
65	1.4D	None	50	.727	100	6	C	
			100	.663	100	18		
			150	.670	100	36		
			200	.645	100	48		
			250	.633	100	66		
			300	.629	100	78		
64	1.8D	None	50	.724	100	24	C	Some coning, decreased as speed went up.
			100	.698	100	30		
			150	.691	100	48		
			200	.681	100	54		
			250	.670	100	66		
			300	.668	100	78		

TABLE XII PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
46	1.0D	None	50	.557	100	0	C	
			100	.609	100	12		
			150	.602	100	24		
			200	.610	100	36		
			250	.606	100	48		
			300	.605	100	60		
45	1.4D	None	50	.775	100	6	C	
			100	.661	100	24		
			150	.667	100	30		
			200	.681	100	42		
			250	.678	100	66		
			300	.679	100	96		
44	1.8D	None	50	.803	100	6	C	
			100	.714	100	24		
			150	.719	100	24		
			200	.725	100	42		
			250	.731	100	60		
			300	.732	100	90		

TABLE XIII PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
43	1.0D	None	50	.660	100	30	C	Coning
			100	.618	100	48		
			150	.620	100	66		
			200	.613	100	96		
			250	.624	100	108		
			300	.632	100	144		
42	1.4D	None	50	.691	100	0	C	Coning nearly gone.
			100	.675	100	84		
			150	.699	100	90		
			200	.695	100	90		
			250	.706	100	132		
			300	.709	100	162		
58	1.8D	None	50	.787	100	0	C	Very slight coning.
			100	.712	100	60		
			150	.754	100	114		
			200	.764	100	126		
			250	.772	100	180		
			300	.779	100	240		

TABLE XIV PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
74	1.0D	6 3/4" Wire	50	.633	97.7	30	C	
			100	.553	90.2	54		
			150	.539	90.1	78		
			200	.542	92.3	102		
			250	.533	91.3	120		
			300	.525	90.7	132		
70	1.4D	8 1/4" Wire	50	.691	95.0	18	C	
			100	.588	88.7	42		
			150	.604	90.1	66		
			200	.597	92.6	84		
			250	.595	94.0	102		
			300	.593	94.3	120		
71	1.8D	8 1/4" Wire	50	.700	96.7	30	C	
			100	.614	88.0	48		
			150	.625	90.4	72		
			200	.622	91.3	90		
			250	.615	91.8	114		
			300	.614	91.9	132		

TABLE XV PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION - HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
62	1.0D	6" Wire	50	.636	114.2	18	C	
			100	.575	94.4	24		
			150	.569	94.5	36		
			200	.572	93.8	48		
			250	.566	93.4	66		
			300	.573	94.7	78		
52	1.4D	7 3/4" Wire	50	.681	87.9	24	C	
			100	.650	98.3	36		
			150	.639	95.8	48		
			200	.647	95.0	66		
			250	.643	94.8	84		
			300	.649	95.6	108		
53	1.8D	7 3/4" Wire	50	.694	86.4	6	C	
			100	.669	93.7	24		
			150	.679	94.4	36		
			200	.675	93.1	48		
			250	.667	91.2	60		
			300	.670	91.5	72		

TABLE XVI PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION – HEM WIRE

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
54	1.0D	6 3/4" Wire	50	.618	93.6	18	C	
			100	.607	98.2	54		
			150	.620	100.0	54		
			200	.614	100.2	72		
			250	.614	98.4	96		
			300	.617	97.6	120		
57	1.0D	6" Wire	50	.672	101.8	18	C	
			100	.602	97.4	36		
			150	.599	96.6	54		
			200	.606	98.9	78		
			250	.606	97.1	102		
			300	.601	95.1	126		
50	1.4D	7 3/4" Wire	50	.703	101.7	18	C	
			100	.672	99.6	66		
			150	.689	98.6	66		
			200	.697	100.3	84		
			250	.672	95.2	114		
			300	.677	95.5	144		
51	1.8D	7 3/4" Wire	50	.797	101.3	6	C	
			100	.690	96.9	36		
			150	.707	93.8	42		
			200	.703	92.0	66		
			250	.696	90.2	90		
			300	.698	89.6	114		

TABLE XVII PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
96	1.0D	7 1/4" Band	50	.689	106.3	42	C	
			100	.578	94.3	78		
			150	.579	96.8	108		
			200	.577	98.3	144		
			250	.568	97.3	162		
			300	.568	98.1	174		
83	1.4D	8 1/8" Band	50	.624	85.8	18	C	
			100	.611	92.2	42		
			150	.623	93.0	48		
			200	.624	96.7	66		
			250	.616	97.3	78		
			300	.614	97.6	90		
82	1.8D	8 1/8" Band	50	.694	95.9	12	C	
			100	.632	90.5	24		
			150	.632	91.5	36		
			200	.632	92.8	48		
			250	.632	94.3	60		
			300	.625	93.6	78		

TABLE XVIII PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
16 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
95	1.0D	7 1/4" Band	50	.654	117.4	18	C	
			100	.603	99.0	42		
			150	.585	97.2	60		
			200	.589	96.6	72		
			250	.592	97.7	78		
			300	.588	97.2	84		
85	1.4D	8 1/8" Band	50	.754	97.3	0	C	
			100	.638	96.5	12		
			150	.645	96.7	18		
			200	.640	94.0	30		
			250	.638	94.1	36		
			300	.636	93.7	42		
84	1.8D	8 1/8" Band	50	.772	96.1	0	C	Suspension lines uneven.
			100	.638	89.4	6		
			150	.650	91.7	18		
			200	.659	90.9	18		
			250	.648	88.6	24		
			300	.656	89.6	30		

TABLE XIX PARACHUTE TEST DATA

CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$
24 SUSPENSION LINES
HEM CONFIGURATION - HEM BAND

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
99	1.0D	7 1/4" Band	50	.691	104.7	12		
			100	.594	96.1	24		
			150	.599	96.6	42		
			200	.592	96.6	54		
			250	.587	94.1	60		
			300	.597	94.5	78	C	
92	1.4D	8 1/8" Band	50	.684	99.0	12	C	Some coning.
			100	.617	91.4	48		
			150	.633	90.6	54		
			200	.649	93.4	72		
			250	.647	91.6	90		
			300	.647	91.3	108		
91	1.8D	8 1/8" Band	50	.575	66.6	12	C	
			100	.620	88.6	24		
			150	.654	88.1	54		
			200	.660	87.8	90		
			250	.661	85.8	90		
			300	.662	85.9	108		

TABLE XX PARACHUTE TEST DATA

CLOTH PERMEABILITY 8 $FT^3/FT^2/MIN$
8 SUSPENSION LINES
HEM CONFIGURATION - UNMODIFIED

RUN NO.	LINE LENGTH	HEM	V FPS	C_D	% REEFED	ROTATION RATE RPM	ROTATION DIRECTION	REMARKS
105	1.0D	None	50	.818	100	174	C	Coning greatly. Rotation data inaccurate due to oscillation in mech. (Approx. 30° from axis)
			100	.746	100	288		
			150	.740	100	324		
			200	.740	100	282		
104	1.4D	None	50	.906	100	42	C	Coning greatly. (Approx. 30° from axis)
			100	.786	100	66		
			150	.789	100	120		
			200	.767	100	180		
103	1.8D	None	50	.915	100	12	C	Coning greatly. (Approx. 30° from axis)
			100	.812	100	24		
			150	.828	100	24		
			200	.819	100	36		
			250	.808	100	102		

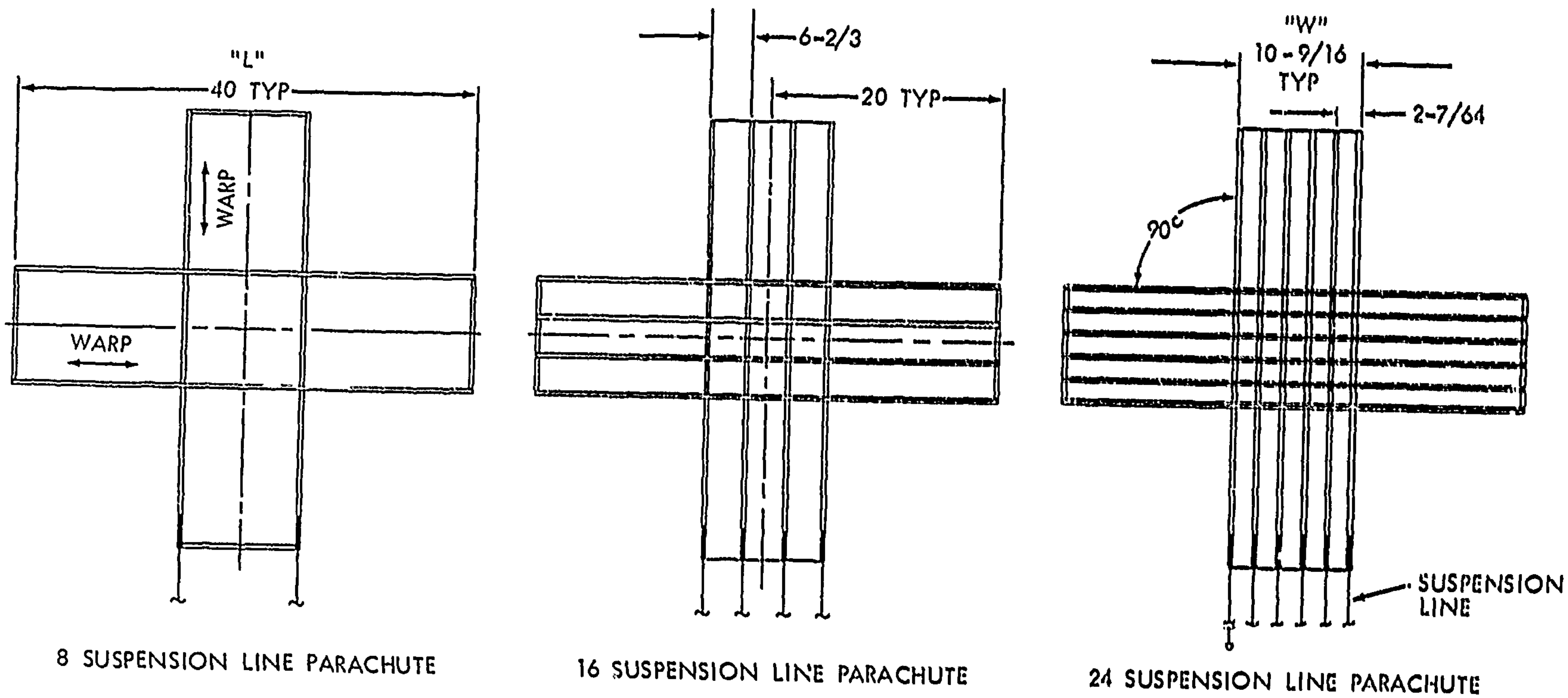
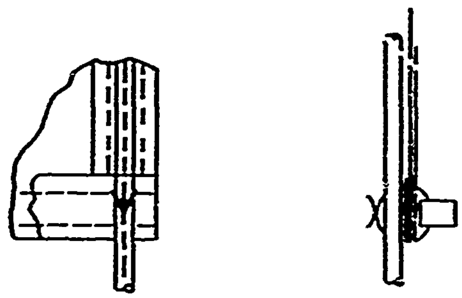
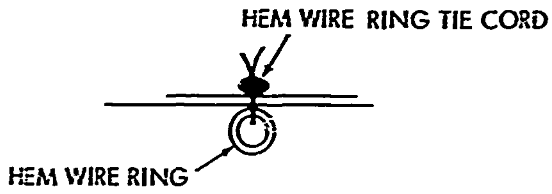


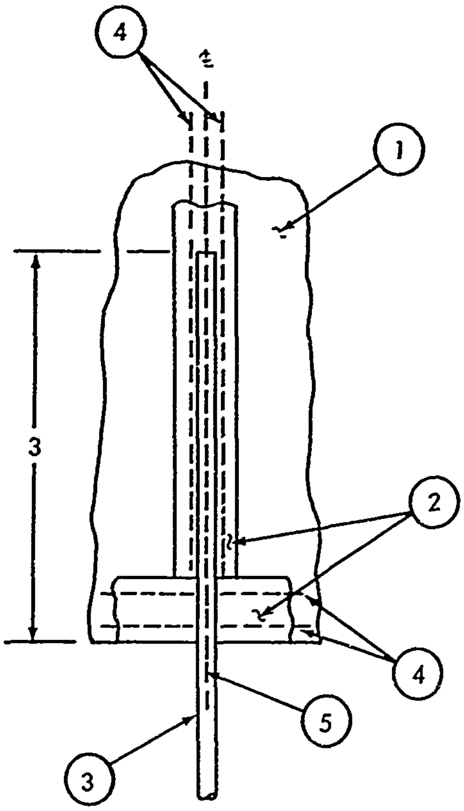
FIG. 1 MODEL PARACHUTE CONFIGURATIONS-CONSTRUCTION DETAILS ARE SHOWN IN FIG. 2



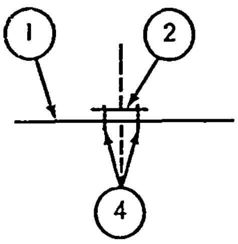


1/4 O.D. x 3/16 I.D. x 1/8 LONG

HEM WIRE RINGS INSTALLED ON
OUTER SUSPENSION LINES

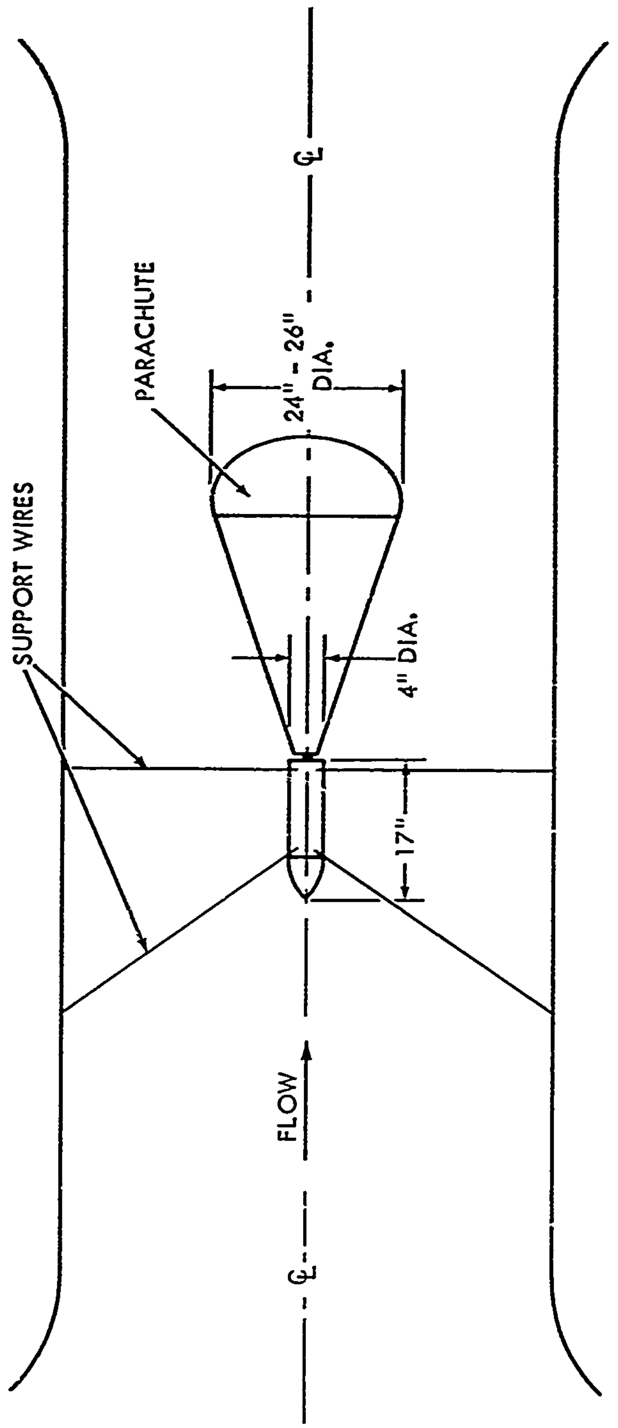


SKIRT HEM - SUSPENSION LINE ASS'Y



TYPICAL TAPE - CANOPY CROSS SECTION

FIG. 2 MODEL PARACHUTE CONSTRUCTION DETAILS
SEE TABLE I FOR MATERIALS IDENTIFICATION



WIND TUNNEL CROSS SECTION DIMENSIONS 7 FT × 11 FT

FIG. 3 WIND-TUNNEL SUPPORT SYSTEM

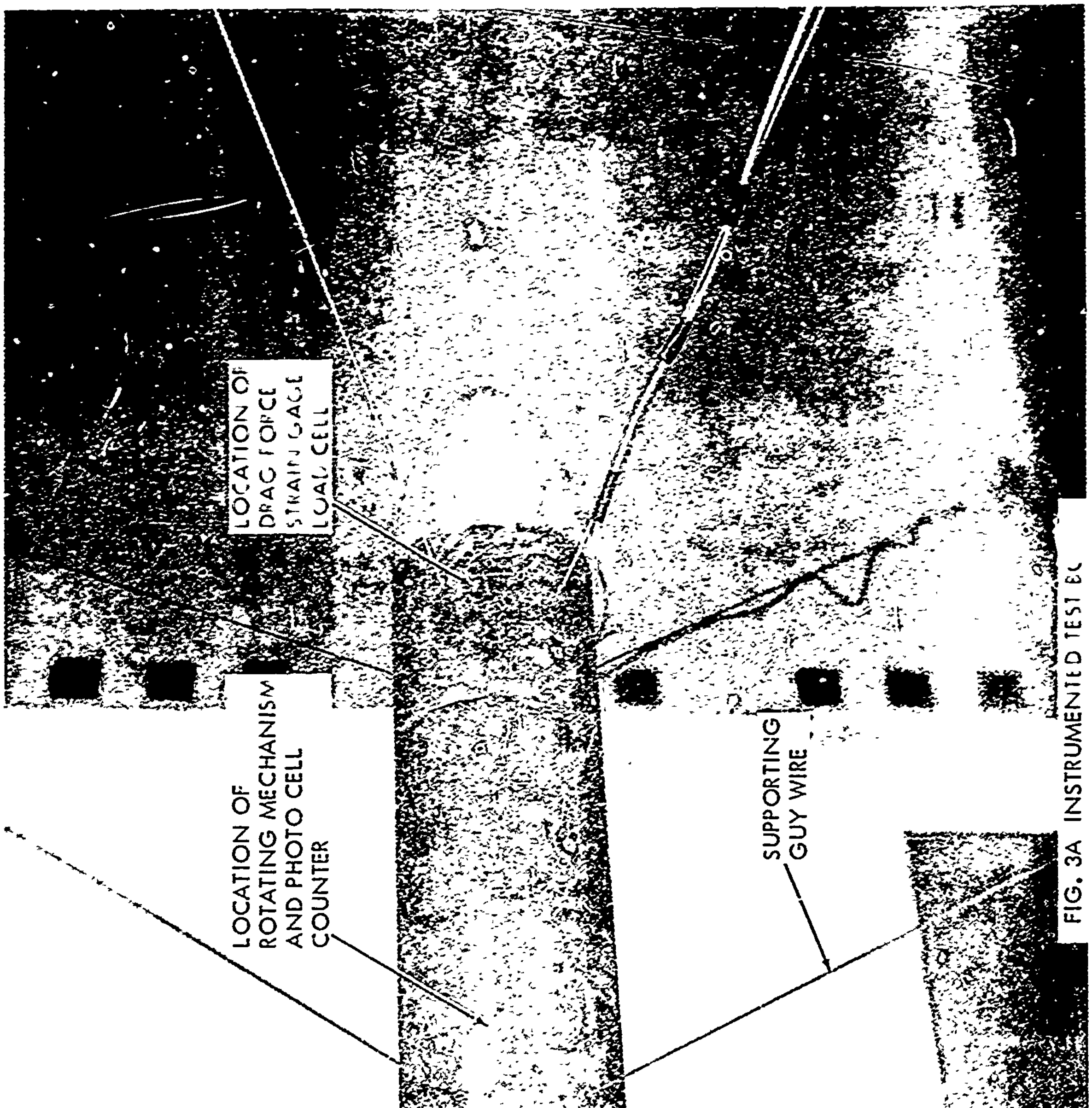


FIG. 3A INSTRUMENTED TEST BC

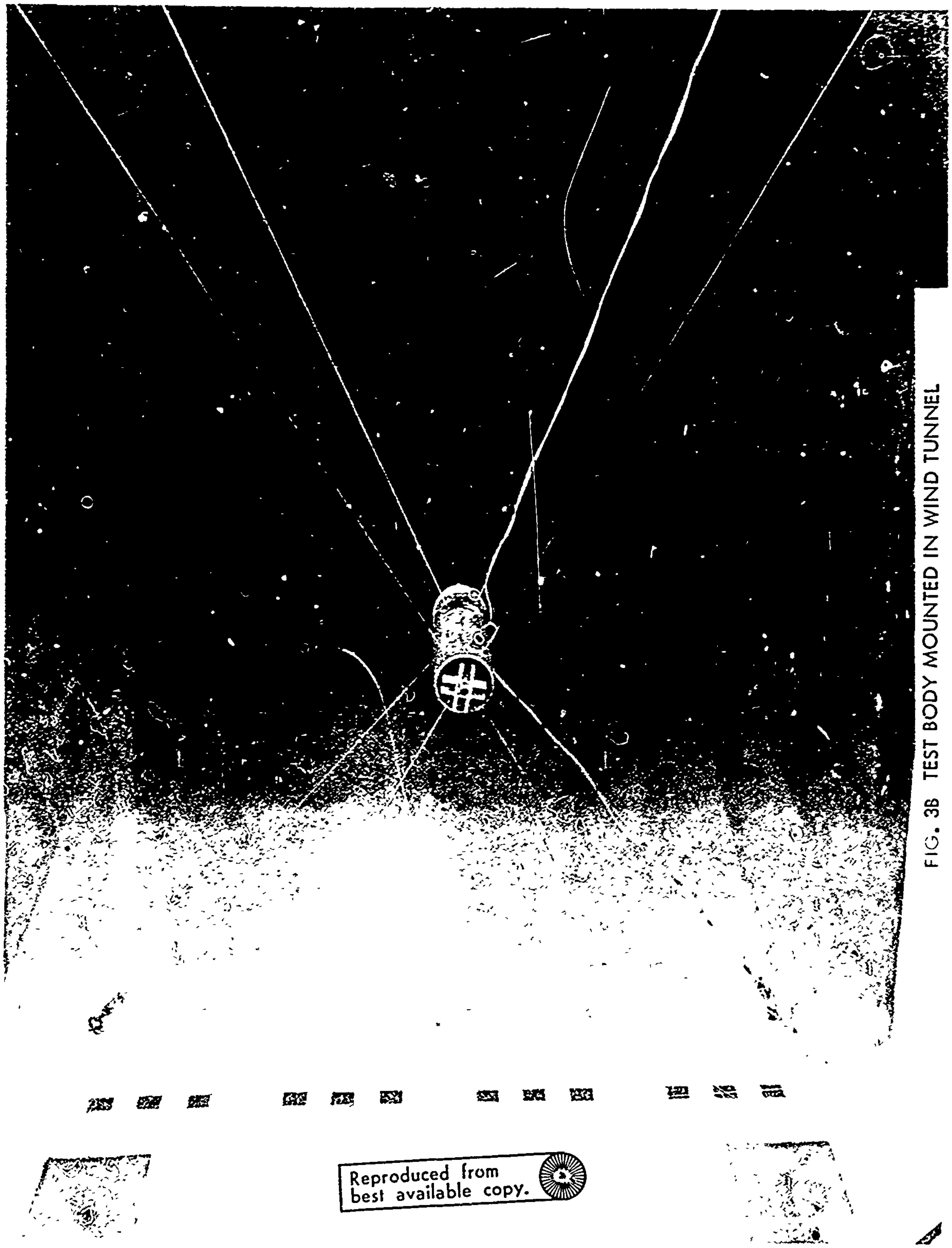


FIG. 3B TEST BODY MOUNTED IN WIND TUNNEL

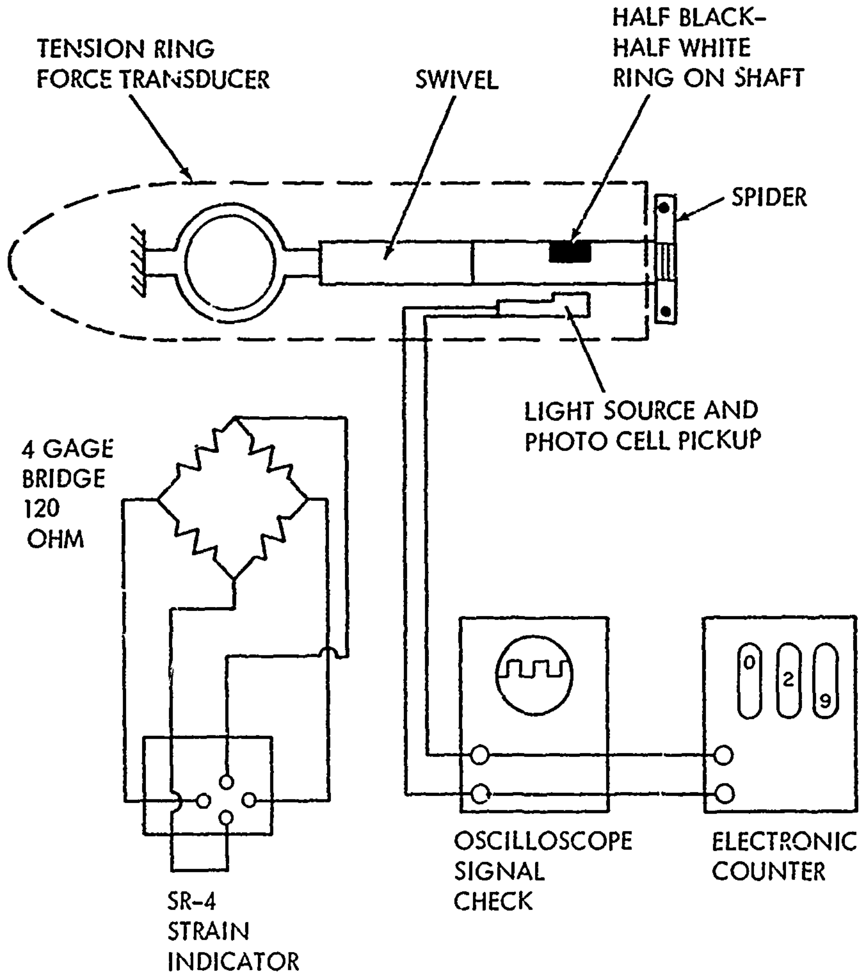


FIG. 4 SCHEMATIC OF TEST INSTRUMENTATION

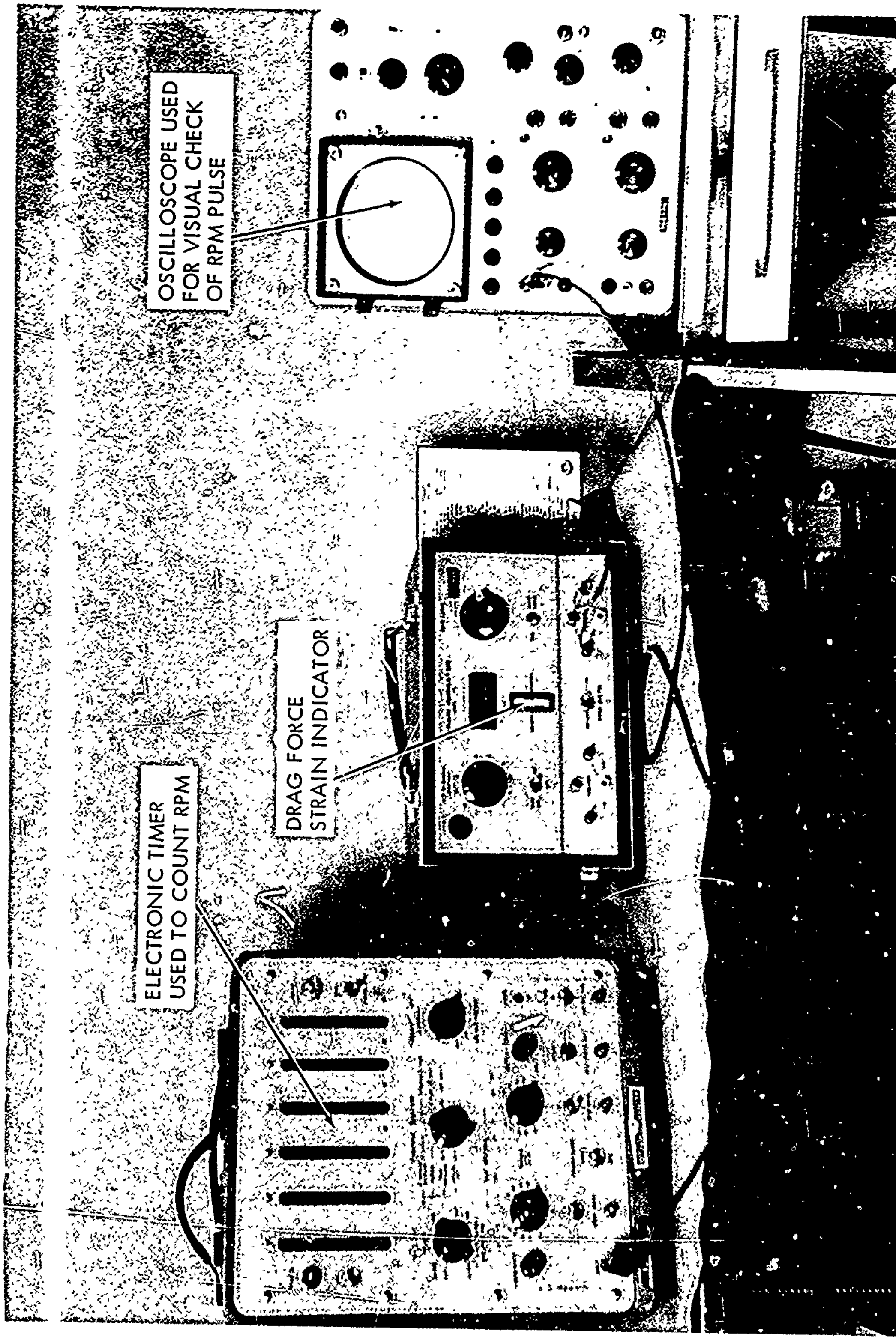


FIG. 4A TEST INSTRUMENTATION

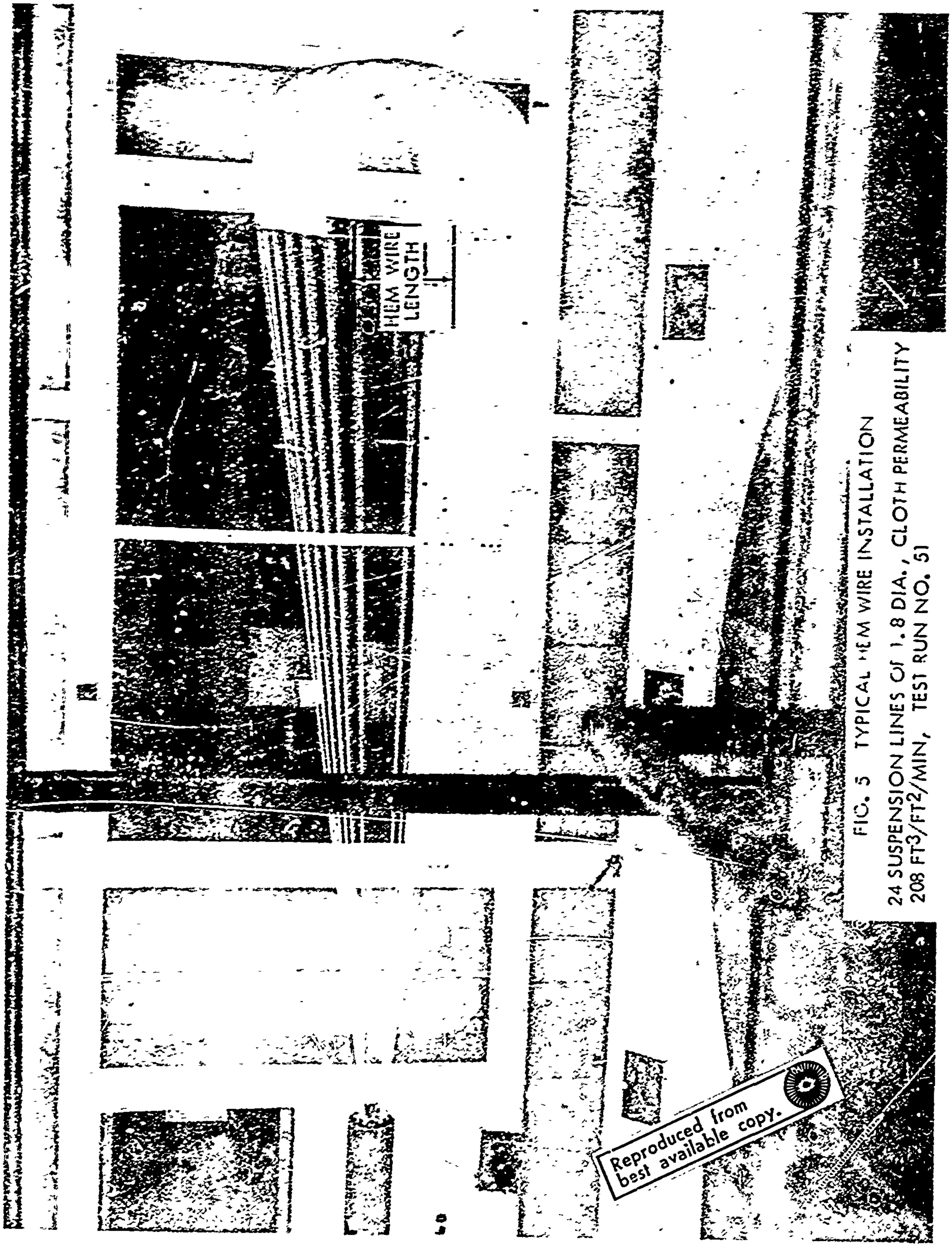


FIG. 5 TYPICAL HEM WIRE INSTALLATION

24 SUSPENSION LINES OF 1.8 DIA., CLOTH PERMEABILITY 208 FT^3/FT^2/MIN, TEST RUN NO. 51

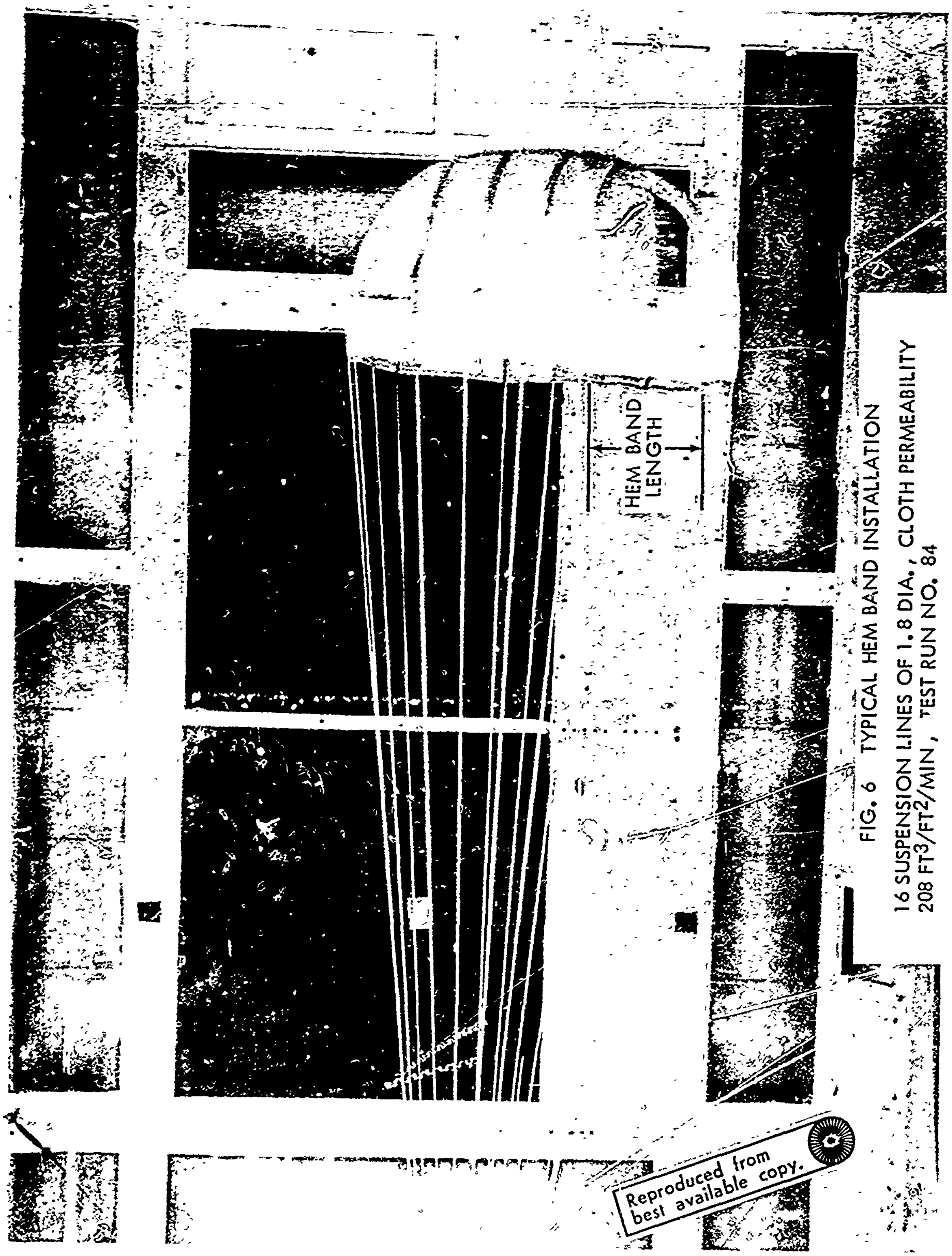


FIG. 6 TYPICAL HEM BAND INSTALLATION

16 SUSPENSION LINES OF 1.8 DIA., CLOTH PERMEABILITY 208 $FT^3/FT^2/MIN$, TEST RUN NO. 84

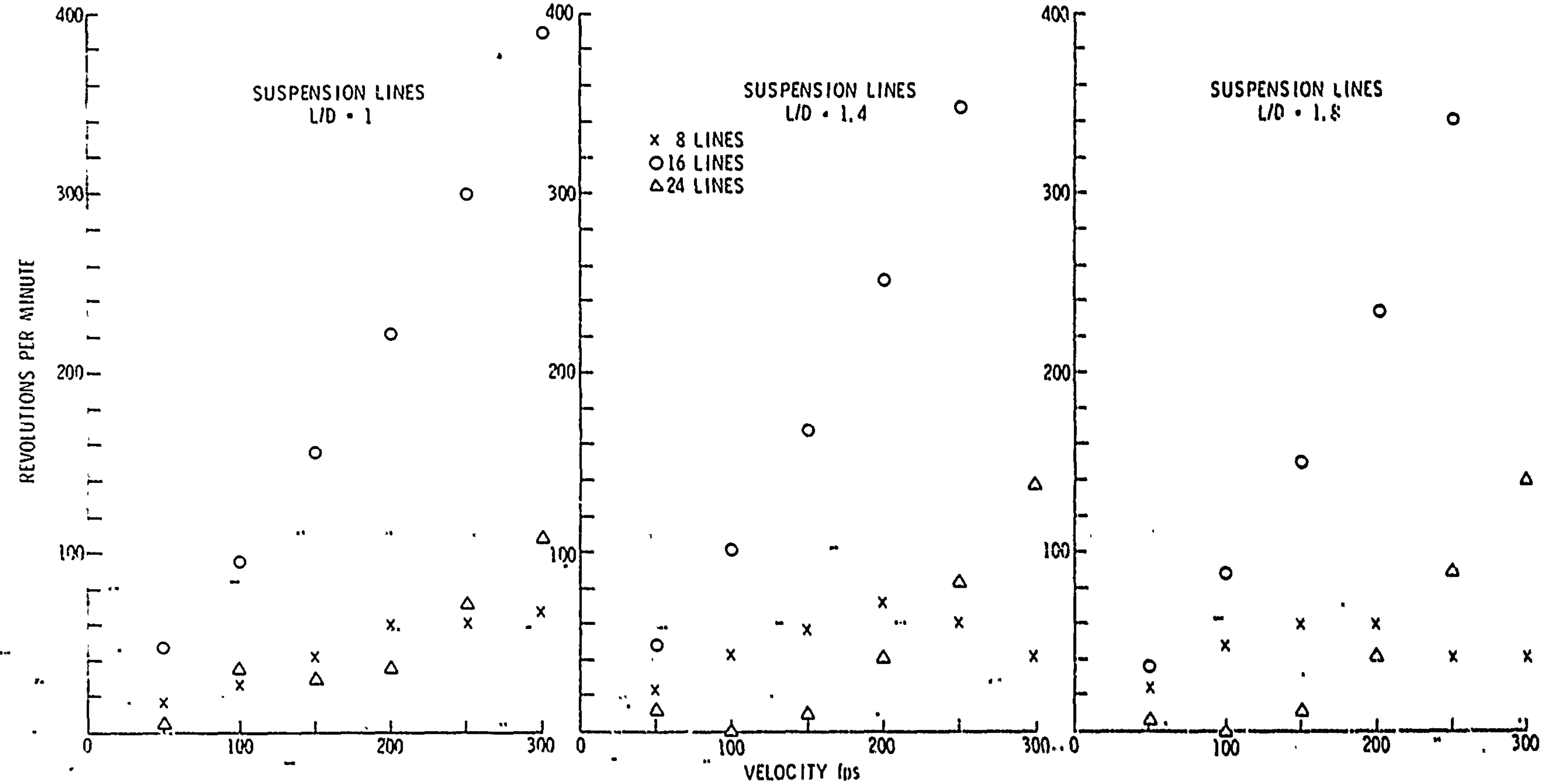


FIG. 7 SPIN RATE VERSUS VELOCITY, CANOPY CLOTH PERMEABILITY-
80 FT^3/FT^2/MIN, HEM MODIFICATION - NONE

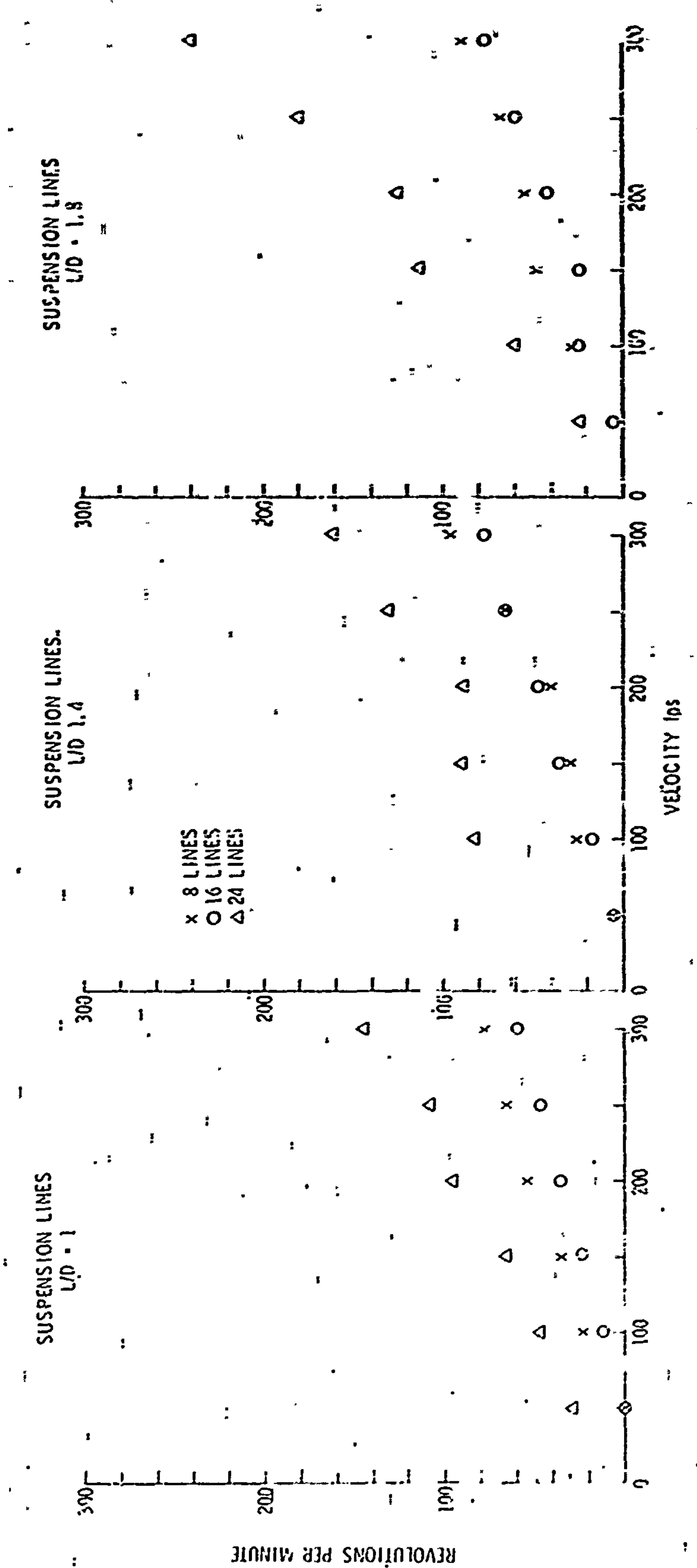


FIG. 8 SPIN RATE VERSUS VELOCITY, CANOPY CLOTH PERMEABILITY - 208 $FT^3/FT^2/MIN$, HEM MODIFICATION - NONE

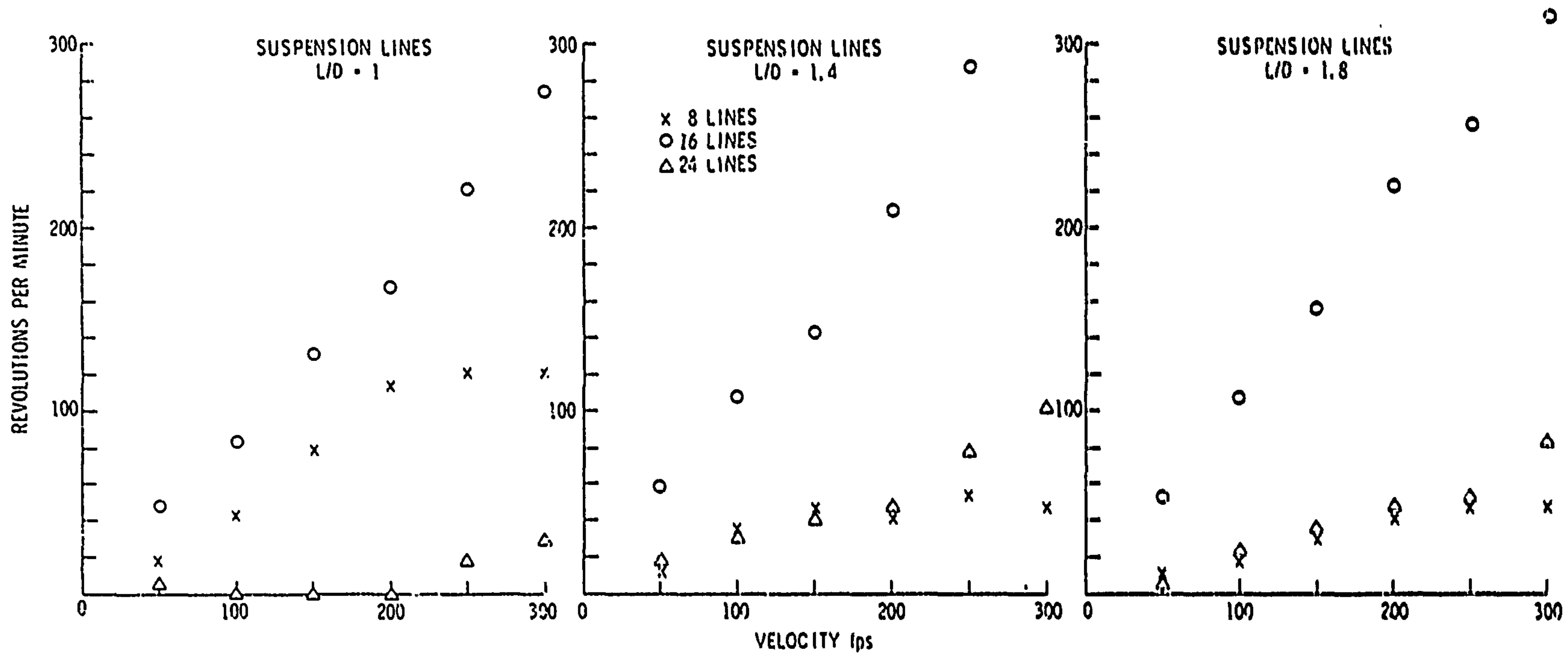


FIG. 9 SPIN RATE VERSUS VELOCITY, CLOTH PERMEABILITY - 80 $FT^3/FT^2/MIN$, HEM MODIFICATION - HEM WIRE

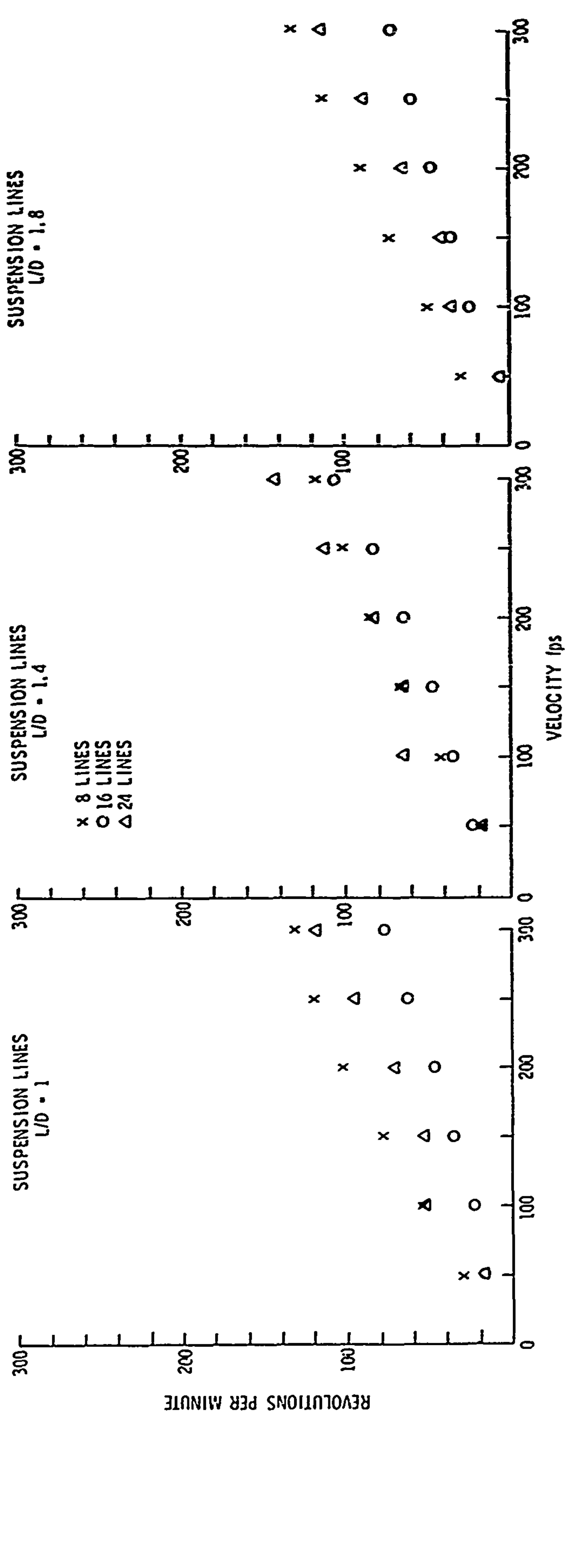


FIG. 10 SPIN RATE VERSUS VELOCITY, CANOPY CLOTH PERMEABILITY = 208 $FT^3/FT^2/MIN$, HEM MODIFICATION - HEM WIRE

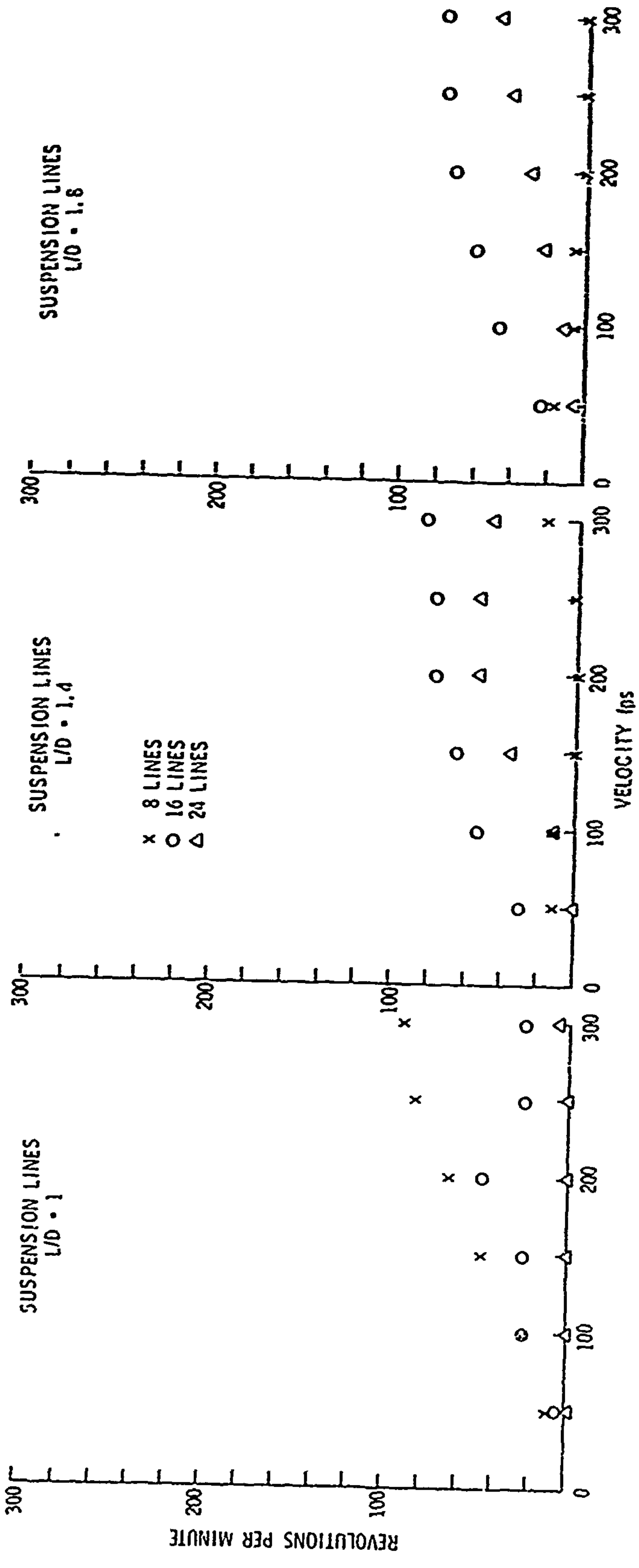


FIG. 11 SPIN RATE VERSUS VELOCITY, CANOPY CLOTH PERMEABILITY - 80 $FT^3/FT^2/MIN$, HEM MODIFICATION - HEM BAND

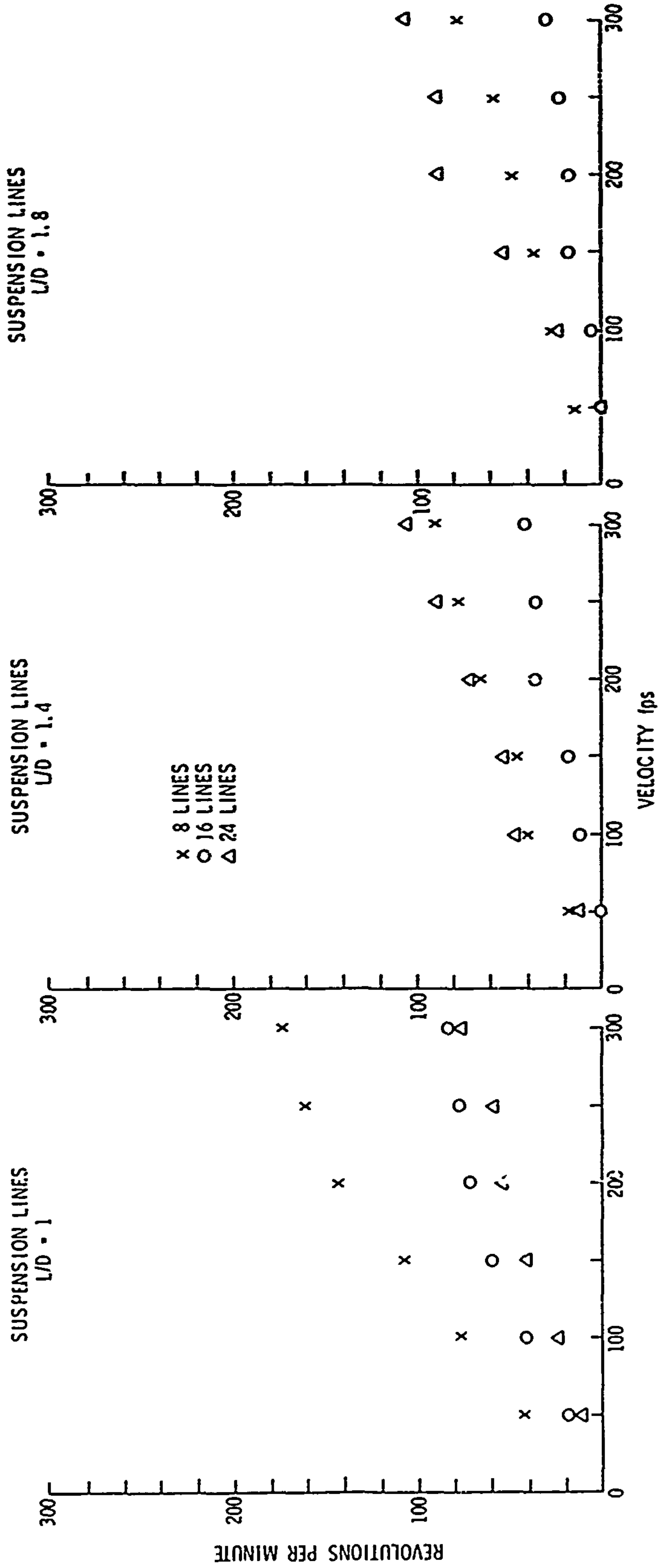


FIG. 12 SPIN RATE VERSUS VELOCITY, CANOPY CLOTH PERMEABILITY - 208 FT^3/FT^2/MIN, HEM MODIFICATION - HEM BAND